



Study Area

The Hanford Reach is the area of the Columbia River that extends from Priest Rapids Dam (River Mile 397) for 51 miles to the head of McNary Pool (RM346) near Richland, Washington. It is the longest remaining free-flowing stretch of the Columbia



Cooperative Study

The study was conducted cooperatively by the U.S. Fish and Wildlife Service, Columbia River Inter-Tribal Fish Commission, Alaska Department of Fish and Game, U.S. Geological Survey, Washington Department of Fish and Wildlife, the Yakama Nation and Nugent GIS and Environmental Services of Seattle and Cexec Incorporated of Dulles, Virginia.

U.S. Fish & Wildlife Service

FACT SHEET

Cooperative study of Stream-flow Fluctuations on Fall Chinook in the Hanford Reach Area of the Columbia River

Introduction and Background:

Conducted from 2002 to 2005, the study evaluated the effects of upstream dam operations on spawning and rearing conditions for fall Chinook in the Hanford Reach. Specifically, the study focused on the effects of stream-flow and stream-flow variations on adult salmon spawning habitat, juvenile salmon rearing habitat and juvenile salmon entrapment and stranding mortality.

The Hanford Reach, near Richland, Washington, is the last significant non-tidal, un-impounded portion of the Columbia River still accessible to salmon. It supports the largest, most productive population of wild salmon remaining in the Pacific Northwest. These fall Chinook, called upriver brights, are a cornerstone in efforts to preserve and restore widely depleted Columbia Basin salmon stocks. They are a primary stock supporting Columbia River Treaty Indian subsistence and commercial fisheries, as well as non-Indian sport and commercial fisheries. They also contribute significantly to ocean sport and commercial fisheries as far north as southeast Alaska.

Hanford fall Chinook are one of the few remaining Columbia River populations that have not been listed under the Endangered Species Act. The Hanford population remains strong because critical spawning and rearing habitats in the Hanford Reach are largely intact. However, this healthy population could be even stronger with adjustments in flow fluctuations.

Of particular concern are the effects of seasonal and daily flow regulation and operation of upstream dams on the quantity and quality of habitat available for fall Chinook spawning and rearing, and on mortality of juvenile fish due to stranding or entrapment. Daily flows fluctuate as much as 6 vertical feet in an hour and 12 vertical feet in 4 hours. These fluctuations have significant effects on spawning habitat for adult fish during the fall and on mortality of juvenile fish due to stranding and/or entrapment during spring.

The release of this study does not represent a final decision or policy by the U.S. Fish and Wildlife Service.

Study Conclusions:

Entrapment: Our study results confirm that flow fluctuations due to dam operations cause significant mortality of juvenile fall Chinook that rear in the Hanford Reach. These impacts appear to be significantly greater than those previously estimated. Our observations of significant entrapment in spite of current protection measures highlight the importance of developing operational and streamflow management plans that are more effective at minimizing juvenile mortality and stabilizing habitat conditions.

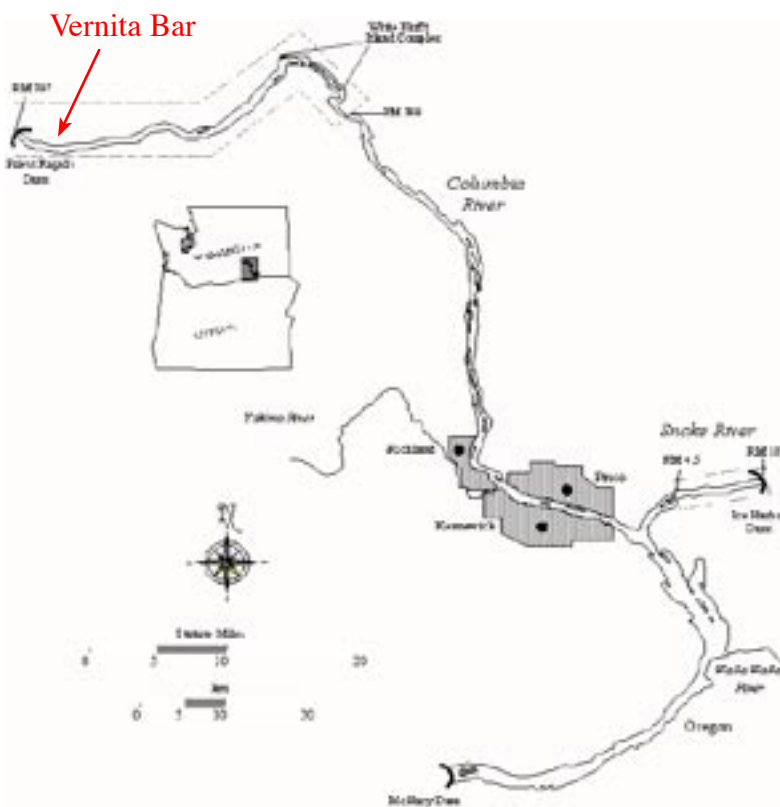
Based on our study results, there is little quantitative basis for assuming that flow fluctuations at low flows are more harmful than the same fluctuations at high flow levels, or vice versa. In addition, the evaluation of alternative hydrographs indicated that the impact could be reduced by controlling the size and frequency of flow fluctuations, and the results of the field work suggests that the timing of fluctuations (early vs. late rearing season) could also be used to reduce the impacts. The simulation results suggest that reducing flow fluctuations has considerable potential for reducing mortality levels if fluctuation magnitudes are kept below 10,000 cubic feet per second (10 kcfs). The predicted number of entrapped Chinook dramatically increased as flow

fluctuations increased to 20 kcfs, 30 kcfs and 40 kcfs.

It appears that fluctuations above 10 kcfs produce dramatic increases in the number of fish entrapped. The size and frequency of flow fluctuations were directly related to the number of entrapments created. Considering the results of the re-regulation analysis, we believe the physical ability exists to control flow fluctuation magnitude and frequency to the extent required to reduce expected juvenile Chinook mortality impacts. The analysis

both limit the number of flow reductions and their magnitude.

Spawning habitat: To better understand the effects of the current altered hydrographs on spawning habitat availability and persistence, our plan is to continue and complete current spawning habitat model investigations. Significant progress has been made in terms of understanding the effect of spatial and temporal variation in physical conditions along the Reach, and the spawning habitat model developed during this study



of the capability of the Priest Rapids and Wanapum projects to re-regulate and reduce flow fluctuations indicated that flexibility may exist within “normal” operating limits to

provides a sound basis for the next steps to complete model building work. We identified and applied the important concept of persistence of suitable conditions across the

variable hourly hydrograph. We also identified variables that are important for predicting fall Chinook spawning habitat, and gained insight into the level of contrast required to increase confidence in our habitat simulations. These accomplishments have provided the foundation for the next steps in our research to build a spawning habitat model or models that will assist managers in planning and predicting with confidence

and spatially variable habitat conditions. Stable flows also reduce the potential for stranding or entrapment of juveniles.

Possible Benefits of the Study:

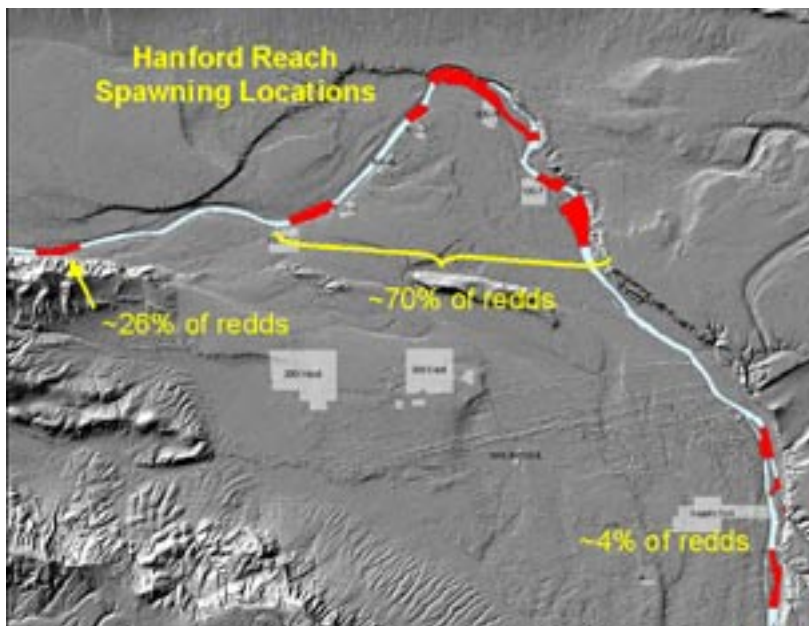
The study better defines the Reach's production potential and limitations and helps to identify effective protection, restoration and management alternatives for this still-strong fall Chinook population. Study results also will help guide development

ultimately lead to benefits for dam operations by providing more flexibility than the current management regime.

Approach and Methods:

This study builds on earlier work to address information gaps and other limitations on our understanding of the effects of stream-flow and stream-flow variation on adult salmon spawning habitat, juvenile salmon rearing habitat and juvenile salmon entrapment and stranding mortality.

While previous studies have provided valuable information, application of the results has been limited primarily to the Vernita Bar area of the Reach for spawning-flow management and to the middle section of the Reach for rearing-flow management and stranding/entrapment mortality estimates. This study shows that fall Chinook spawning is concentrated in 10 different areas of the upper, middle and lower Reach (from Vernita Bar to Wooded Island) and that juveniles rear throughout the area.



Nine primary spawning areas in the Hanford Reach.

the desired strategy to achieve management goals for fall Chinook production.

Rearing habitat: Although rearing habitat varies with stream-flow, stability is likely more important to juvenile Chinook than the absolute flow level. Stable flows and habitat conditions require less movement and less energy expenditure than constantly fluctuating flows

of sustainable escapement goals and fisheries by the Pacific Salmon Commission, Pacific Fisheries Management Council, and the Columbia River Fish Management Plan. In addition to benefiting fishery conservation, and improving stock productivity, effective application of study results may

The general approach of the study was the use of two hydrodynamic models to produce the detailed physical output required for the entrapment evaluation and habitat assessment. The first is a one-dimensional flow model developed by Pacific Northwest National Laboratories (referred to as the Modular Aquatic

Simulation System-1D (MASS1). The second is a two-dimensional depth-averaged flow model (River2D). Several efforts were required to develop River2D. The vast majority of the data was acquired from a Compact Hydrographic Airborne Rapid Total Survey (CHARTS) conducted by the U.S. Army Corps of Engineers. The final digital elevation model (DEM) included data from six data sets varying in resolution density and spatial extent. These sets include:

(More details on the hydrodynamic models and methods adapted, developed and employed in these assessments are in the study report.)

Areas of Study Emphasis

1) Spawning habitat –

The objectives of the spawning habitat assessment were to:
1) Examine distribution of spawning habitat



Fish mortality occurs primarily when fish are stranded and when entrainments drain. Warming of water in entrainments causes thermal mortality

1) CHARTS; 2) Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS); 3) Deep-water bathymetric survey; 4) USGS 10-meter DEMs; 5) USACE-surveyed cross sections and 6) white sturgeon project cross sections.

throughout the Reach;
2) Identify physical characteristics of spawning sites, including parameters related to stream-flow and fluctuations;
3) Build a model that could explain patterns of Chinook spawning habitat selection using variables

that explicitly accounted for the dynamic nature of the physical conditions; and
4) Evaluate the effects of stream-flow and stream-flow variability on spawning habitat within the Reach.

Spawning distribution was based both on historic aerial surveys and peak redd counts, and on aerial surveys of redd locations during 2001 and 2004. A new multivariate logistic habitat-use model was derived based on physical variables that best explained patterns in occurrence of redds and characterized the dynamic nature of the varying physical conditions within the Reach. The study relied on a combination of various stream-flows and habitat-use models to estimate suitable spawning habitat areas under a variety of flow regimes.

Modeling demonstrated that the greater the fluctuation in flows, the greater the impact on available spawning habitat. For a given hydrograph at Priest Rapids Dam, the sharpest flow fluctuations occur at Vernita Bar, thus the predicted amount of spawning habitat decreased significantly with each increase in fluctuation magnitude.

Results confirm that the variability and complexity associated with natural geomorphic features and a relatively natural flow regime are important factors for restoring or maintaining fall Chinook productivity. Increasing steady-state stream flows between 40 kcfs and 100 kcfs increased the available habitat with suitable depths and velocities for spawning in each of the areas examined.

Development of the digital elevation model and the hydrodynamic model for the Reach has provided the tools to determine relevant physical metrics associated with specific stream flows throughout the Reach. The model-building and testing process provided the first step in evaluating the relationship between persistence of conditions across widely fluctuating flows and the associated fish responses. Using these tools

and results can contribute to understanding the effects of dam operations on fall Chinook productivity.

2) Juvenile rearing habitat

The objectives of assessing rearing habitat were to: 1) Identify the distribution of juveniles rearing throughout the Reach; 2) Explore daytime and nighttime behavior relative to habitat use and the potential for entrapment; 3) Quantify the amount of rearing habitat in the entire Reach for a range of flows; and 4) Examine the flow-

related distribution of that habitat.

Seining surveys were conducted to evaluate seasonal changes in the relative abundance, distribution and length-composition of fall Chinook in near-shore habitats. Video surveys were used to examine fall Chinook behaviors that may lead to stranding and entrapment. Rearing habitat-use was described with an existing model developed by Tiffan et al (2002). Effects of stream-flow on rearing



Flow fluctuations from hydropower operations. These photos were taken just three hours apart.

habitat availability were based on simulations with a combination of various stream-flows, and habitat-use models.

The amount of juvenile fall Chinook rearing habitat in the Reach increased as flows decreased because of shallower near-shore slopes and reduced water velocities. The number and size of distinct patches of rearing habitat also varied with flow. As in the Tiffin et

larger habitat patches may pose less risk of predation or energetic costs than movement between smaller patches of suitable rearing habitat.

3) Entrapment/stranding mortality –

The objectives of the entrapment/stranding evaluation were to: 1) Develop a quantitative estimate of fall Chinook entrapment mortality in the entire Reach; 2) Evaluate

Entrapments occur when flows drop and isolated pools of water are created, trapping fish in shallow water where they can be easy targets for predators or suffer from the effects of water that gets too warm. Stranding occurs when water levels quickly drop and fish are stranded on de-watered river banks and island shores. Previous studies have documented significant entrapment and stranding losses of juvenile fall Chinook in the Hanford Reach.

Although fall Chinook mortality is caused by both entrapment and stranding, our study focused on entrapments because they provide a more tractable index for assessing the minimum impacts due to flow fluctuations downstream from Priest Rapids Dam. Entrapments are well-defined, temporally stable, geographic locations.



Juveniles are entrapped in these nearshore areas.

al (2002) study, this study shows that between 77 to 97 percent of the shorelines in the middle segment of the Reach provide suitable rearing habitat for fall Chinook. At lower flows, rearing habitat has fewer numbers of large habitat patches, indicating that rearing habitat is more connected than at higher flows. Movements within

the impacts on entrapment of alternative dam operations; and 3) Identify operational alternatives that may help to reduce impacts of fluctuations on juvenile entrapment.

Flow fluctuations in the Reach can create hundreds and even thousands of entrapments during a single fluctuation event.

Several methods were used to assess entrapment. Field crews physically counted selected entrapment fish sampling sites throughout the Reach. In addition, weekly surveys were conducted with fixed-wing aircraft using video recorders along with real-time counts providing qualitative data on the

distribution, relative numbers and locations along where entrapment densities were high. A third method included walking shoreline surveys (from River Kilometer 546 to River Kilometer 639) to identify and map entrapments capable of holding water and entrapping fish.

These surveys were conducted by a crew of approximately 14 people from US Fish and Wildlife Service, US Geological Survey, Washington Department of Fish and Wildlife, Nugent GIS and Environmental Services and the Yakima Nation using Trimble GPS receivers.

During these surveys, a total of 7,932 individual entrapments were counted. Large numbers of entrapments were identified in all three segments of the Reach: 36 percent in the upper, 33 percent in the middle and 31 percent in the lower segment. During the spring 2003 juvenile Chinook rearing period, an estimated 126,226 entrapments occurred, for an average of 1,503 per day.

Roughly 1.6 million young Chinook were entrapped in 2003 with a mortality rate of about 82%.

Recommendations:

Spawning Habitat:

- A monitoring program should be implemented to collect comprehensive biological data on adult fall Chinook responses to hourly flow fluctuations during the spawning season. This effort should focus on the White Bluffs area in addition

throughout the season to avoid redd superimposition.

- Studies should be conducted to determine the level of daytime and nighttime spawning activity.
- Studies should be conducted to determine the extent, location, and physical characteristics associated with deep-



White Bluffs – middle segment of the Reach and primary spawning area.

- to Vernita Bar and the other spawning areas in the lower Reach.
- Because the majority of fall Chinook spawning occurs in the middle segment, operations at Priest Rapids Dam should be structured for the desired effect at the White Bluffs area.
- Tiered operations should be investigated to determine the utility of providing spawning habitat at different flow levels and locations

water spawning.

- Additional work should be conducted to determine other geomorphic features that might be influential in spawning site selection by fall Chinook, including an investigation into the feasibility of predicting hyporheic flow or upwelling using geomorphic models.
 - Aerial photography linked to global positioning systems should be conducted on a
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regular basis to determine patterns in timing and location of spawning activity throughout the spawning season.

- Work should continue to determine the carrying capacity for various flow levels and hydrographs so operations can be crafted to accommodate expected escapement levels.

Entrapment:

- Continue the fish sampling program during the emergence and rearing periods to estimate the total number of fish entrapped using our modeling framework. The sampling effort should be kept at a level similar to the 2003 effort or increased to reduce the resulting uncertainty in the estimate.
- Develop and implement a study plan to evaluate entrapment fish sampling efficiency.
- Complete the enumeration of entrapments, especially at the lower flow levels.
- Develop and

implement planned flow manipulation experiments to quantify the diel impact on fish per entrapment.

- Develop and implement a plan to estimate the effect of fluctuating flows on ***stranding*** of juvenile Chinook, and design a statistically rigorous sampling program to survey stranding areas.
- When stranding field studies are complete, incorporate an evaluation component for stranding into our modeling evaluation system.
- Investigate the role of water temperature as it relates to stranding and entrapment susceptibility.
- Continue with the development and evaluation of alternative operations and determine their effects on Chinook stranding and entrapment.

- Conduct a focused study on the impact of various ramping rates on entrapment and stranding.
- Conduct a more rigorous abundance index seining program to determine if such a program can be linked to subsequent entrapment and stranding locations and magnitudes. The index seining could then potentially be used as a monitoring tool.
- Conduct a focused study on predation rates on stranded and entrapped fish.

For a Copy of the Full Text:

The study, titled “Effects of Hydropower Operations on Spawning Habitat, Rearing Habitat and Stranding/Entrapment Mortality of Fall Chinook Salmon in the Hanford Reach of the Columbia River,” can be found at:

<http://www.fws.gov/pacific/columbiariver/>
